U.S. DEPARTMENT OF ENERGY

Isotope Program

Isotopes
For Science, Industry, and Medicine
U.S. Department of Energy

Product and Services Catalog

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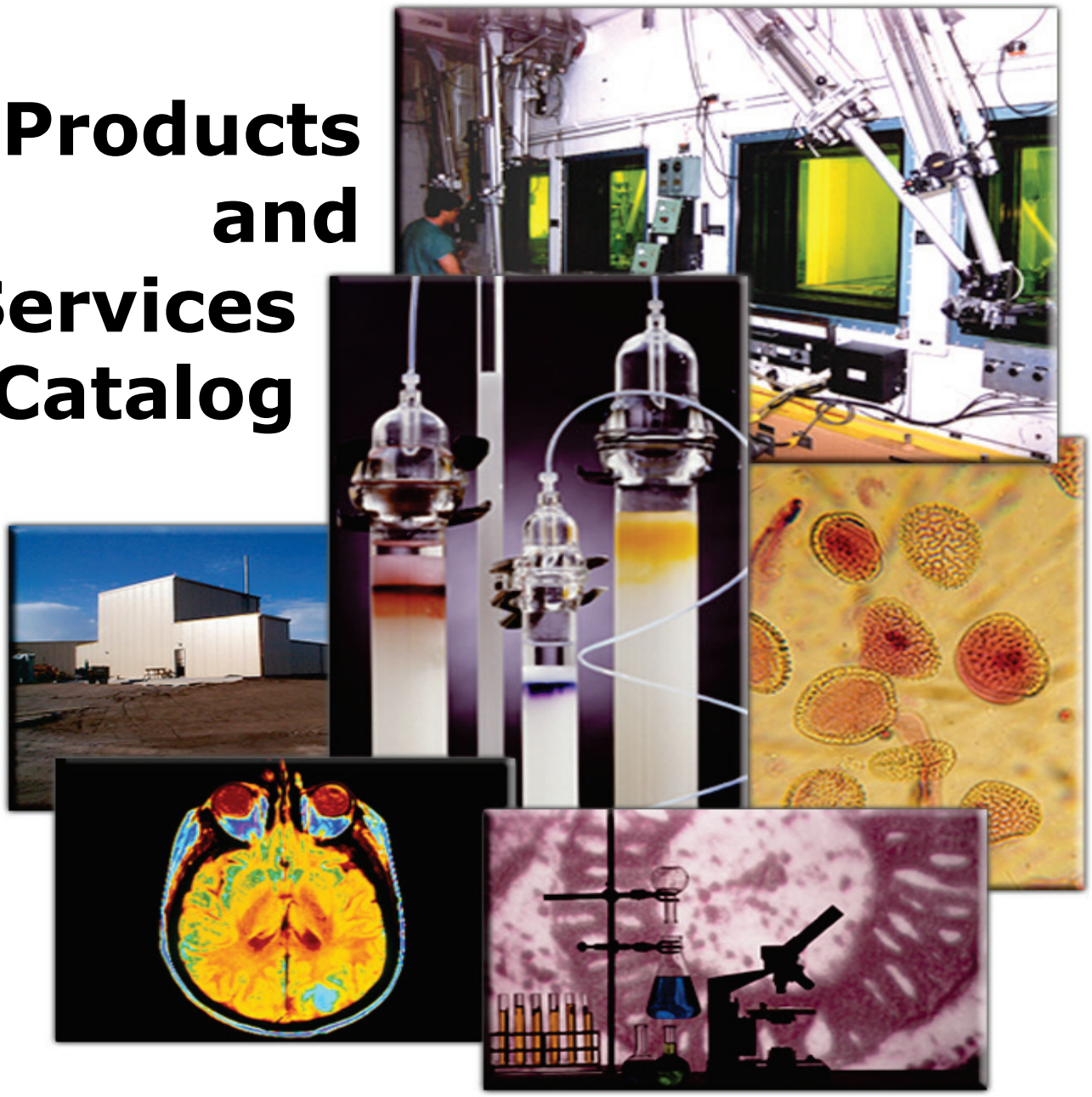
Products and Services Catalog



The Department of Energy's (DOE) Isotope Development and Production for Research and Applications Program (IDPRA) is managed by the Office of Nuclear Physics and provides a wide range of isotope products and services to customers worldwide. Continuing a long tradition within the DOE and its predecessor organizations, it is committed to produce and distribute radioisotopes and enriched stable isotopes for research or development purposes, medical diagnoses and therapy, industrial, homeland security, agricultural, and other useful applications that are in the national interest. It is centrally managed from DOE Headquarters in Germantown, Maryland. Currently, DOE is maintaining isotope production facilities at Brookhaven National Laboratory, Idaho National Laboratory, Los Alamos National Laboratory, Pacific Northwest National Laboratory, and Oak Ridge National Laboratory. In addition, the DOE has established the National Isotope Development Center (NIDC) as a virtual service organization which interfaces with the user community and manages the coordination of isotope production across the program facilities. The Isotope Business Office (IBO) manages the business operations involved in the production, sale, and distribution of isotopes. For ordering isotopes or for additional information on isotopes and isotope services, contact the IBO at Oak Ridge National Laboratory. More detailed product information can be found in the online catalog at: www.isotopes.gov

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PRODUCTS that are offered for sale are listed in this catalog. Materials either exist in inventory or can be scheduled to be produced at one or more facilities. Isotopes are sold in forms suitable for incorporation by purchasers into diverse pharmaceuticals, generator kits, irradiation targets, radiation sources, or other finished products. Stable enriched isotopes in stock may be purchased or leased for non-consumptive use.

SERVICES are available based on the DOE's extensive expertise derived from many years of isotope research, development, and production operations. These services include chemical processing, target and source irradiations, research, development and testing capabilities, chemical form conversions, and source encapsulations.

TO ORDER, contact the IBO. Buyers will be required to provide complete but brief documentation. Purchasers can obtain the order forms, instructions, and assistance necessary for a transaction from the IBO at Oak Ridge National Laboratory. Order forms are also available as part of the online catalog. The DOE Headquarters office is available to coordinate among production sites or to receive and direct inquiries.

AVAILABILITY of products and services described in this catalog varies, and DOE distribution of some products may not be feasible at some times. However, the DOE is eager to work with its current and potential customers to establish new means of production and new products as warranted by demand and national need. If specific products and services are not listed, inquiries are welcomed and encouraged.

PRICES, terms and other conditions of purchase are established by the DOE. Price changes may be necessary at any time. However, confirming a purchase order assures that prices stated therein will apply for the term of the order. Estimates of prices can be obtained from the IBO. Firm quotations are developed during the ordering process.

Radioisotopes

Actinium-225
Decay: 10.0 days to bismuth-213, multiple alpha and beta emission to stable ^{209}Bi
Major Radiation: α-8.38 MeV, β^-_{max}-1.42 MeV
Form: dried nitrate, 5.80 x 10^4 Ci/g; carrier free, >98% ^{225}Ac radiopurity
Also available as a Ac-225/Bi-213 generator.

Aluminum-26
Decay: 7.17 x 10^5 years to magnesium-26
Major Radiation: β^+_{max}-1.17 MeV, γ-1,809 keV
Form: aluminum (III) in 1 M HCl, >0.01 µCi/ml, >99% radiopurity

Americium-243
Decay: 7.37 x 10^3 years to neptunium-239
Major Radiation: α-5.27 MeV
Form: oxide powder, 0.2 Ci/g, >99.9% radiopurity

Arsenic-73
Decay: 80.3 days to germanium-73
Major Radiation: γ-53.4 keV
Form: arsenic (V) in <0.1M HCl
Source: by proton in rubidium chloride targets

Bismuth-207
Decay: 32.2 years to lead-207
Major Radiation: γ-1.7702 MeV
Form: bismuth (III) in > 4.0 M HNO_3, > 20 µCi/ml, >99% radiopurity

Cadmium-109
Decay: 462.6 days to silver-109
Major Radiation: γ-88 keV
Form: cadmium (II) in 1 M HCl, >10 mCi/ml, >99.9% radiopurity (excluding Cd-113m)

Californium-252
Decay; 2.645 years to curium-248
Major Radiation: α particles and fission neutrons
Form: solution or custom forms, >80-85 atom % radiopurity

Cobalt-60
Decay: 5.27 years to nickel-60
Major Radiation: β^-_{max}-318 keV, γ-1.333 MeV
Form: nickel-plated pellets (1mm x 1 mm), wire, or cobalt rods, up to 250-300 Ci/g, >99% radiopurity

Copper-67
Decay: 2.580 days to zinc-67
Major Radiation: β^-_{max}-580 keV, γ-184.6 keV
Form: copper (II) in 0.1-1.0 M HCl, >10-20 mCi/ml, >99% radiopurity (excluding Cu-64)

Curium-244
Decay: 18.11 years to plutonium-240
Major Radiation: α-5.81 MeV, fission neutrons
Form: oxide or nitrate, variable radiopurity

Curium-248
Decay: 3.4 x 10^5 years to plutonium-244
Major Radiation: α-5.08 MeV
Form: solid nitrate or chloride, ~97% radiopurity

Germanium-68
Decay: 270.8 days to gallium-68
Major Radiation: β^+_{max}-1899 keV, annihilation γ-511 keV
Form: germanium (IV) in <1.0M HCl

Holmium-166
Decay: 26.8 hours to erbium-166
Major Radiation: γ-80 keV, β^-_{max}- 666 keV
Form: holmium chloride in 0.1 M HCl, >99% radiopurity

Holmium-166m
Decay: 1,200 years, to erbium-166M
Major Radiation: β^-_{max}- 65 keV
Form: oxide, 1 mCi/g; variable radiopurity

Iridium-192
Decay: 73.83 days to platinum-192
Major Radiation: β^-_{max}-672 keV, γ-468 keV
Form: thin wires only

Iron-55
Decay: 2.7 years to magnesium-55
Major Radiation: X-ray-5.89 keV
Form: metal, ~120 Ci/g, variable radiopurity

Nickel-63
Decay: 101 years to copper-63
Major Radiation: β^-_{max}-66.9 keV
Form: chloride solution or dried chloride solid, >10 C/g, >99% radiopurity

Plutonium-238
Decay: 87.7 years to uranium-234
Major Radiation: α-5.49 MeV
Form: oxide powder, 80-97% radiopurity

Plutonium-239
Decay: 24,100 years to uranium-235
Major Radiation: α-5.15 MeV
Form: oxide powder, 99.00-99.99% radiopurity

Plutonium-240
Decay: 6,560 years to uranium-236
Major Radiation: α-5.16 MeV
Form: oxide powder, 75-95% radiopurity

Plutonium-241
Decay: 14.4 years to uranium-237
Major Radiation: α-4.9 MeV
Form: oxide powder, 80-93% radiopurity

Plutonium-242
Decay: 3.76 x 10^5 years to uranium-238
Major Radiation: α-4.9 MeV
Form: oxide powder, >99% radiopurity

Polonium-209
Decay: 102 years to lead-205
Major Radiation: α-4.9 MeV
Form: 5 M nitric acid, ~5µCi/ml, >99% radiopurity (<1% Po-210)

Radium-223
Decay: 11.4 days through decay chain of six short-lived members
Major Radiation: α-5.6 to 5.7 MeV
Form: dry solid, carrier-free, >99.99%

Selenium-75
Decay: 119.78 days to arsenic-75
Major Radiation: γ-279.5 keV
Form: selenium (VI) in 6.0 M HCl, >1.0 mCi/ml, >99% radiopurity (excluding 8.5 day Se-72)

Silicon-32
Decay: ~100 years to phosphorus-32
Major Radiation: β^-_{max}-221 keV
Form: silicates in 0.1 M NaOH, ~11.8 µCi/ml, >99.9% radiopurity

Sodium-22
Decay: 2.605 years to neon-22
Major Radiation: β^+_{max}-546 keV, γ-1274.5 keV
Form: Na (I) in 0.1 M HCl, >10 mCi/ml, >99.9% radiopurity

Strontium-82
Decay: 25.55 days to rubidium-82
Major Radiation: β^+_{max}-511 keV
Form: Strontium chloride in 0.1-0.5 M HCl, >10 mCi/ml, >99% radiopurity (excluding Sr-85)

Strontium-85
Decay: 64.84 days to rubidium-85
Major Radiation: γ-514.0 keV
Form: Strontium (II) in 0.1 M HCl, >1 mCi/ml, >99% radiopurity (excluding <0.5% Sr-82)
Source: by protons in natural molybdenum targets

Technetium-99
Decay: 2.13 x 10^5 years to ruthenium-99
Major Radiation: β^-_{max}-293.6 keV
Form: solid ammonium pertechnetate, typically 17 mCi/g, >99% radiopurity

Thorium-227
Decay: 18.7 days to 11.4 day radium-223
Major Radiation: α-5.7 to 6.0 MeV
Form: dry solid, carrier-free, >99.99%

Thorium-229
Decay: 7.3 x 103 years to radium-225
Major Radiation: α-4.8453 MeV
Form: dried nitrate, α-4.8453 MeV, ~0.213 Ci/g, >99% radiopurity (α pulse activity 36%)

Tin-117m
Decay: 14 days to stable tin-117
Major Radiation: γ-158.56 keV
Form: tin metal in quartz tube of tin (IV) in 0.1 M HCl, 4-8 Ci/g, > 99% radiopurity

Tungsten-188/Rhenium-188 Generator
Decay: W-188 parent, 69 days to rhenium-188; Re-188 daughter, 16.9 hours to osmium-188
Major Radiation: W-188: γ-220 and 290 keV; Re-188: γ-155 keV, β^-_{max}-764 keV
Form: W-188 as tungstic acid absorbed on alumina in glass column; Re-188 eluted as sodium perrhenate with saline solution, 4-5 mCi/mg W-188, 75-85% Re-188/bolus, based on W-188 parent
Also available as a W-188 solution

Uranium-234
Decay: 2.46 x 10^5 years to thorium-230
Major Radiation: α-4.77 MeV
Form: oxide, 6.25 mCi/g, >95% radiopurity

Uranium-235
Decay: 7.04 x 10^8 years to thorium-231
Major Radiation: α-4.39 MeV
Form: oxide, ~2.16 µCi/g, >98% radiopurity

Uranium-238
Decay: 4.47 x 10^9 years to uranium-234
Major Radiation: α-4.20 MeV
Form: oxide, ~0.336 µCi/g, >99.9% radiopurity

Yttrium-88
Decay: 106.6 days to strontium-88
Major Radiation: β^+_{max}-760 keV, γ-1,836 keV
Form: yttrium (III) in 0.1 M HC1, >1.0 mCi/ml, >99% radiopurity

Zinc-65
Decay: 243.8 days to copper-65
Major Radiation: γ-1115.5 keV, β^+_{max}-325 keV
Form: zinc (II) in 0.1-0.5 M HCl, >1 mCi/ml, >99% radiopurity

Zirconium-88
Decay: 84.3 days to yttrium-88
Major Radiation: γ-392.9 keV
Form: Zirconium (IV) in 2.0M HCl >99% radiopurity
Source: by protons in molybdenum targets

Stable Isotopes

The DOE has a large supply of many stable isotopes at various isotopic enrichments. Below is a list of these isotopes, including the isotopic enrichments, standard form and alternate form (in italics). Isotopes are listed alphabetically by common name.

Antimony
Form: metal, *oxide*, *sulfide*

Sb-121	Isotopic enrichment	>99%
Sb-123	Isotopic enrichment	>99%

Argon
Form: gas

Ar-36	Isotopic enrichment	>99.9%
Ar-40	Isotopic enrichment	>99.95%

Barium
Form: carbonate, *nitrate*, *chloride*, *metal, oxide*

Ba-130	Isotopic enrichment	8-37%
Ba-132	Isotopic enrichment	21-28%
Ba-134	Isotopic enrichment	73%
Ba-135	Isotopic enrichment	79-93%
Ba-136	Isotopic enrichment	92-95%
Ba-137	Isotopic enrichment	81-89%
Ba-138	Isotopic enrichment	>97%

Bromine
Form: sodium and ammonium bromide*, bromides of magnesium, potassium, silver*

Br-79	Isotopic enrichment	90-99%
Br-81	Isotopic enrichment	>97%

Cadmium
Form: oxide, *chloride*, *bromide*, *iodide*, *sulfide*, *metal, nitrate, sulfate*

Cd-106	Isotopic enrichment	79-88%
Cd-108	Isotopic enrichment	68-69%
Cd-110	Isotopic enrichment	93-97%
Cd-111	Isotopic enrichment	92-96%
Cd-112	Isotopic enrichment	>97%
Cd-113	Isotopic enrichment	91-95%
Cd-114	Isotopic enrichment	>98%
Cd-116	Isotopic enrichment	93-98%

Calcium
Form: carbonate, *chloride, oxide*, *nitrate*, *metal*, *gluconate, iodide, fluoride*

Ca-40	Isotopic enrichment	>99.8%
Ca-42	Isotopic enrichment	92-94%
Ca-43	Isotopic enrichment	61-83%
Ca-44	Isotopic enrichment	79-98%
Ca-46	Isotopic enrichment	4-30%
Ca-48	Isotopic enrichment	66-97%

Cerium
Form: oxide, *hydrated nitrate*, *metal, chloride*

Ce-136	Isotopic enrichment	21-50%
Ce-138	Isotopic enrichment	17-26%
Ce-140	Isotopic enrichment	>99%
Ce-142	Isotopic enrichment	83-92%

Chlorine
Form: chloride of sodium, *potassium*, *silver*, *barium*, magnesium, or *lead, calcium, ammonium*

Cl-35	Isotopic enrichment	>99%
Cl-37	Isotopic enrichment	95-98%

Chromium
Form: oxide, *metal powder*

Cr-50	Isotopic enrichment	75-97%
Cr-52	Isotopic enrichment	>99.7%
Cr-53	Isotopic enrichment	95-98%
Cr-54	Isotopic enrichment	90-96%

Copper
Form: oxide, *metal powder, metal, nitrate, sulfate, chloride*

Cu-63	Isotopic enrichment	>99.6%
Cu-65	Isotopic enrichment	>99.4%

Dysprosium
Form: oxide, *metal*, *nitrate, chloride*

Dy-156	Isotopic enrichment	20-21%
Dy-158	Isotopic enrichment	20-32%
Dy-160	Isotopic enrichment	69-78%
Dy-161	Isotopic enrichment	90-95%
Dy-162	Isotopic enrichment	92-96%
Dy-163	Isotopic enrichment	89-96%
Dy-164	Isotopic enrichment	92-98%

Erbium
Form: oxide, *metal*, *nitrate, chloride*

Er-162	Isotopic enrichment	27-34%
Er-164	Isotopic enrichment	67-92%
Er-166	Isotopic enrichment	96%
Er-167	Isotopic enrichment	91%
Er-168	Isotopic enrichment	95-97%
Er-170	Isotopic enrichment	95-96%

Europium
Form: oxide, *metal*, *nitrate, chloride*

Eu-151	Isotopic enrichment	91-96%
Eu-153	Isotopic enrichment	98%

Gadolinium
Form: oxide, *metal*, *nitrate, chloride*

Gd-152	Isotopic enrichment	32-42%
Gd-154	Isotopic enrichment Second pass 92.2% (special product)	65-66%
Gd-155	Isotopic enrichment Second pass 99.8% (special product)	84-94%
Gd-156	Isotopic enrichment	82-99%
Gd-157	Isotopic enrichment	79-88%
Gd-158	Isotopic enrichment	81-97%
Gd-160	Isotopic enrichment Second pass 99.9% (special product)	95-98%

Gallium
Form: oxide, *metal*

Ga-69	Isotopic enrichment	>99%
Ga-71	Isotopic enrichment	>99%

Germanium
Form: oxide, *metal*

Ge-70	Isotopic enrichment	84-98%
Ge-72	Isotopic enrichment	90-98%
Ge-73	Isotopic enrichment	83-94%
Ge-74	Isotopic enrichment	94-98%
Ge-76	Isotopic enrichment	73-92%

Hafnium
Form: oxide, *metal*, *crystal bar*

Hf-174	Isotopic enrichment	6-19%
Hf-176	Isotopic enrichment	63-77%
Hf-177	Isotopic enrichment	84-91%
Hf-178	Isotopic enrichment	87-94%
Hf-179	Isotopic enrichment	81-86%
Hf-180	Isotopic enrichment	93-98%

Helium
Form: compressed gas

He-3	Isotopic enrichment	>99.99%

Indium
Form: oxide, *metal*

In-113	Isotopic enrichment	>59-96%
In-115	Isotopic enrichment	>99.9%

Iridium
Form: metal powder

Ir-191	Isotopic enrichment	95-98%
Ir-193	Isotopic enrichment	>98%

Iron
Form: oxide, *metal, nitrate* (+3)*, sulfate* (+2)*, chloride* (+3)

Fe-54	Isotopic enrichment	95-98%
Fe-56	Isotopic enrichment	>99%
Fe-57	Isotopic enrichment	72-92%
Fe-58	Isotopic enrichment	65-82%

Krypton
Form: gas

Kr-78	Isotopic enrichment	8-20%
		50%
		96%
		99%
Kr-80	Isotopic enrichment	71-77%
		90-97 %
Kr-82	Isotopic enrichment	71-77%
		92%
Kr-84	Isotopic enrichment	90-92%
Kr-86	Isotopic enrichment	50-52%
		99-99.99%

Lanthanum
Form: oxide, *nitrate, chloride*

La-138	Isotopic enrichment	6-7%
La-139	Isotopic enrichment	99.99%

Lead
Form: carbonate, *chloride*, *nitrate*, *oxide*, acetate, sulfide, sulfate, *metal pellets*, or *single piece*

Pb-204	Isotopic enrichment	63-99%
Pb-206	Isotopic enrichment	>98%
Pb-207	Isotopic enrichment	92%
Pb-208	Isotopic enrichment	>98%
	Second pass	
	99.9% (special product)	

Lithium
Form: metal, hydroxide monohydrate, *fluoride*, *chloride*, *sulfate*, *carbonate*

Li-6	Isotopic enrichment	95-96%
Li-7	Isotopic enrichment	98-99.9+%

Lutetium
Form: oxide, *metal*, *nitrate, chloride*

Lu-175	Isotopic enrichment	>99.8%
Lu-176*	Isotopic enrichment	44-83%

***NOTE**: Radioactive; half-life 3.73E10 years, theoretical specific activity 5.5E-8 Ci/g.*

Magnesium
Form: oxide, *metal, chloride, sulfate*

Mg-24	Isotopic enrichment	>99.6%
Mg-25	Isotopic enrichment	97-98%
Mg-26	Isotopic enrichment	>98%

Mercury
Form: oxide, *sulfide*, *metal, chloride*

Hg-196	Isotopic enrichment	13-73%
Hg-198	Isotopic enrichment	82-93%
Hg-199	Isotopic enrichment	85-91%
Hg-200	Isotopic enrichment	88-93%
Hg-201	Isotopic enrichment	74-96%
Hg-202	Isotopic enrichment	95-99%
Hg-204	Isotopic enrichment	85-98%

Molybdenum
Form: metal powder, metal, oxide

Mo-92	Isotopic enrichment	90-98%
Mo-94	Isotopic enrichment	82-92%
Mo-95	Isotopic enrichment	89-96%
Mo-96	Isotopic enrichment	91-96%
Mo-97	Isotopic enrichment	83-94%
Mo-98	Isotopic enrichment	95-98%
Mo-100	Isotopic enrichment	91-99%

Neodymium
Form: oxide, *nitrate*, *metal*, *chloride*

Nd-142	Isotopic enrichment	84-98%
Nd-143	Isotopic enrichment	90-91%
Nd-144	Isotopic enrichment	97%
Nd-145	Isotopic enrichment	73-91%
Nd-146	Isotopic enrichment	63-97%
Nd-148	Isotopic enrichment	87-95%
Nd-150	Isotopic enrichment	68-97%

Neon
Form: gas

Ne-22	Isotopic enrichment	71%

Nickel
Form: metal powder, metal, *oxide*, *chloride, carbonate*

Ni-58	Isotopic enrichment	>99.6%
Ni-60	Isotopic enrichment	>98%
Ni-61	Isotopic enrichment	84-99%
Ni-62	Isotopic enrichment	86-96%
Ni-64	Isotopic enrichment	90-99%

Nitrogen
Form: ammonium sulfate

N-15	Isotopic enrichment	67-69%

Osmium
Form: metal, *oxide*

Os-184	Isotopic enrichment	5%
Os-186	Isotopic enrichment	67-79%
Os-187	Isotopic enrichment	34-73%
Os-188	Isotopic enrichment	86-94%
Os-189	Isotopic enrichment	81-95%
Os-190	Isotopic enrichment	95-97%
Os-192	Isotopic enrichment	>98%

Oxygen
Form: water, oxygen gas

O-16	Isotopic enrichment	>99.99%

Palladium
Form: metal, *oxide, chloride*

Pd-102	Isotopic enrichment	73-78%
Pd-104	Isotopic enrichment	86-95%
Pd-105	Isotopic enrichment	90-97%
Pd-106	Isotopic enrichment	96-98%
Pd-108	Isotopic enrichment	96-98%
Pd-110	Isotopic enrichment	97-98%

Platinum
Form: metal sponge, metal powder, metal

Pt-190	Isotopic enrichment	1-4%
Pt-192	Isotopic enrichment	41-56%
Pt-194	Isotopic enrichment	91-96%
Pt-195	Isotopic enrichment	93-97%
Pt-196	Isotopic enrichment	94-97%
Pt-198	Isotopic enrichment	91-95%

Potassium
Form: chloride, *carbonate*, *iodide, nitrate*

K-39	Isotopic enrichment	>99.9%
K-40*	Isotopic enrichment	3.15%
K-41	Isotopic enrichment	>98%

***NOTE**: Radioactive; half-life 1.25E9 years, theoretical specific activity 7.2E-6 Ci/g.*

Rhenium
Form: metal

Re-185	Isotopic enrichment	96%
Re-187*	Isotopic enrichment	96-99%

***NOTE**: Radioactive; half-life 4.5E10 years, theoretical specific activity 4.3E-8 Ci/g.*

Rubidium
Form: chloride, *carbonate*

Rb-85	Isotopic enrichment	>99%
Rb-87*	Isotopic enrichment	97-99%

***NOTE:** Radioactive; half-life 4.89E10 years, theoretical specific activity 8.4E-8 Ci/g.*

Ruthenium
Form: metal powder, *oxide*

Ru-98	Isotopic enrichment	82-89%
Ru-99	Isotopic enrichment	96-97%
Ru-100	Isotopic enrichment	95-97%
Ru-101	Isotopic enrichment	96-97%
Ru-102	Isotopic enrichment	>98%
Ru-104	Isotopic enrichment	>98%

Samarium
Form: oxide, *nitrate*, *metal, chloride*

Sm-144	Isotopic enrichment	85%
Sm-147*	Isotopic enrichment	97-98%
Sm-148	Isotopic enrichment	90-96%
Sm-149	Isotopic enrichment	91-97%
Sm-150	Isotopic enrichment	87-99%
Sm-152	Isotopic enrichment	>97%
Sm-154	Isotopic enrichment	98%

***NOTE:** * Radioactive; half-life 1.06E10 years, theoretical specific activity 2.3E-8 Ci/g.*

Selenium
Form: elemental, *oxide*

Se-74	Isotopic enrichment	55-77%
Se-76	Isotopic enrichment	93-97%
Se-77	Isotopic enrichment	91-94%
Se-78	Isotopic enrichment	97-98%
Se-80	Isotopic enrichment	>99%
Se-82	Isotopic enrichment	87-97%

Silicon
Form: oxide, *elemental powder*, *elemental crystal bar*

Si-28	Isotopic enrichment	>99%
Si-29	Isotopic enrichment	88-95%
Si-30	Isotopic enrichment	83-96%

Silver
Form: metal, *bromide*, chloride, *nitrate*

Ag-107	Isotopic enrichment	>98%
Ag-109	Isotopic enrichment	>97%

Strontium
Form: carbonate, *nitrate*, *metal*, *chloride, oxide*

Sr-84	Isotopic enrichment Second Pass 99.6% (special product)	80-82%
Sr-86	Isotopic enrichment	95-97%
Sr-87	Isotopic enrichment	84-91%
Sr-88	Isotopic enrichment	>99.8%

Sulfur
Form: elemental sulfur hexafluoride, disulfide or powder, sulfides of calcium, iron, potassium, sodium, and zinc

S-32	Isotopic enrichment	>99%
S-33	Isotopic enrichment	17.5%
		88.4%
S-34	Isotopic enrichment	9.8%
		50-52%
		50%
		89-92%
		90-97%
S-36	Isotopic enrichment	1.5-3.5%
		5.9%
		10%
		15-16%
		30%

Tantalum
Form: oxide

Ta-180	Isotopic enrichment	5.7%

Tellurium
Form: elemental, *oxide*

Te-120	Isotopic enrichment	41-56%
Te-122	Isotopic enrichment	94-97%
Te-123	Isotopic enrichment	77-90%
Te-124	Isotopic enrichment	93-98%
Te-125	Isotopic enrichment	93-95%
Te-126	Isotopic enrichment	98%
Te-128	Isotopic enrichment	98-99%
Te-130	Isotopic enrichment	>99%

Thallium
Form: oxide, *metal, chloride, nitrate, sulfide*

Tl-203	Isotopic enrichment	92-97%
Tl-205	Isotopic enrichment	>99%

Tin
Form: oxide, *metal*

Sn-112	Isotopic enrichment	68%
Sn-114	Isotopic enrichment	51-69%
Sn-115	Isotopic enrichment	17-40%
Sn-116	Isotopic enrichment	95-96%
Sn-117	Isotopic enrichment	84-92%
Sn-118	Isotopic enrichment	95-97%
Sn-119	Isotopic enrichment	84-89%
Sn-120	Isotopic enrichment	97-98%
Sn-122	Isotopic enrichment	90-92%
Sn-124	Isotopic enrichment	92-96%

Titanium
Form: oxide, metal, *crystal bar*

Ti-46	Isotopic enrichment	73-96%
Ti-47	Isotopic enrichment	80-94%
Ti-48	Isotopic enrichment	>99%
Ti-49	Isotopic enrichment	66-96%
Ti-50	Isotopic enrichment	67-83%

Tungsten
Form: oxide, *metal powder, ammonium tungstate*

W-180	Isotopic enrichment	6-11%
W-182	Isotopic enrichment	92-94%
W-183	Isotopic enrichment	73-87%
W-184	Isotopic enrichment	93-95%
W-186	Isotopic enrichment	96-99%

Vanadium
Form: oxide

V-50	Isotopic enrichment	36-44%

Xenon
Form: gas

Xe-124	Isotopic enrichment	5-41%
		50-89%
		98.40%
		99.95%
Xe-126	Isotopic enrichment	99%
Xe-129	Isotopic enrichment	88%
Xe-131	Isotopic enrichment	81-87%
Xe-134	Isotopic enrichment	51%
Xe-136	Isotopic enrichment	62-94%

Ytterbium
Form: oxide, *metal*, *nitrate, chloride*

Yb-168	Isotopic enrichment	13-33%
Yb-170	Isotopic enrichment	64-78%
Yb-171	Isotopic enrichment	87-95%
Yb-172	Isotopic enrichment	92-97%
Yb-173	Isotopic enrichment	89-94%
Yb-174	Isotopic enrichment	95-98%
Yb-176	Isotopic enrichment	96-97%

Zinc
Form: oxide, *metal flakes*, *metal, chloride, sulfate, sulfide*

Zn-64	Isotopic enrichment	97-99%
Zn-66	Isotopic enrichment	>98%
Zn-67	Isotopic enrichment	88-94%
Zn-68	Isotopic enrichment	>98%
Zn-70	Isotopic enrichment	65-88%
	Second pass	
	99.7% (special)	

Zirconium
Form: oxide, *crystal bar, metal*

Zr-90	Isotopic enrichment	95-99%
Zr-91	Isotopic enrichment	88-94%
Zr-92	Isotopic enrichment	94-98%
Zr-94	Isotopic enrichment	96-98%
Zr-96	Isotopic enrichment	57-95%

Isotope Services

DOE's isotope production sites offer a wide variety of special custom-order isotope services to complement its radioactive and stable isotope offerings.

Stable Isotope Services

- ***Inorganic compound synthesis and metallurgical, ceramic, and high vacuum processing methods*** are available to process stable isotopes into the desired chemical physical forms to meet customer needs that may be different from the forms listed in the catalog.
- ***Pyrochemical conversion techniques*** (reduction/distillation) to convert rare earth and Group IIA element oxides to high purity metal.
- ***Arc melting casting and alloying*** to prepare metal ingots and to recycle materials, such as foil trimmings and scrap, for further processing and casting shapes.
- ***Hot and cold rolling*** to produce metal foils from the mm to micron range thickness.
- ***Preparation of cold-rolled foils from air-reactive metals*** in micron range thickness.
- ***Wire rolling*** and ***swaging*** processes to prepare metal rods and wires for a variety of applications.
- ***Metal and ceramic powder consolidation*** techniques using cold pressing or cold pressing and sintering to prepare materials. Vacuum hot pressing equipment is available also.
- ***Vanadium-encapsulated neutron dosimeters*** are prepared by sealing very accurately known quantities of well-characterized, enriched stable isotopes or natural elements into small, vanadium capsules for use in making in-core neutron flux measurements.
- ***High vacuum evaporation***-using resistance, radio frequency or electron beam heating techniques is available to prepare thin films and coatings from enriched or natural stable metals, oxides, and other compounds.
- ***Ion beam and plasma sputtering*** equipment is available to produce thin films and coatings from stable, enriched or natural metals, or compounds.
- ***Crystal bar reduction*** process for the preparation of Si, Ti, Zr, and Hf metals is being restored.
- ***Custom targets*** for cyclotrons and accelerators can be fabricated to customer specifications.

Radioisotope Services

- Target Irradiations. Irradiated targets may be supplied to the customer without processing.
- Preparation of custom chemical and physical forms from a variety of radioisotopes may be possible.
- Nuclear Medicine. In addition to Ac-225 and W-188/Re-188 generators, the nuclear medicine staff can provide other radioisotopes and support for development of diagnostic and therapeutic radioisotopes and clinical trials.

National Isotope Development Center
Isotope Business Office
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www.isotopes.gov

PRINT

Ordering Instructions
DOE Order Form, CA-10-90.Com Rev 3

A completed and signed DOE order form, CA-10-90.Com Rev 3, "Isotope and Technical Service Order Form," must be provided by buyers for isotopes and services except for non-U.S. buyers of uranium, plutonium, and thorium. An instruction for completion of the order form follows.

Block 1 – The DOE office or facility contractor address should be provided in **Block 1**. This block is generally completed by the supplying facility.

Block 2 – Most accounting systems require an internal reference purchase order number. **Block 2** is provided for the buyer's referenced purchase order number if applicable.

Block 3 – Complete **Block 3** with the date of your order.

Block 4 – Complete **Block 4** with the exact "Ship to" (consignee) address. Include any "attention" notes or other information to assure proper delivery. A contact person with phone and fax number should be provided.

Block 5 – Complete **Block 5** with the exact address for submitting invoices. Include any "attention" notes or other information to assure proper delivery and payment of the invoice.

Block 6 – If a particular mode of transport, a specific common carrier, or a certain routing is desired, this information should be provided in **Block 6** (note that additional information can be supplied in the body of the order if required). United Parcel Service (UPS) is not currently available for shipment of isotopes. Since shipments are made with transportation charges collect, include a billing account for the selected carrier. If a carrier is not selected or the carrier cannot be utilized, the supplying facility will arrange shipment on a best-method basis. **Note:** On the "Continuation Page" mark the box whether you desire insurance against loss or damage during transport. If the box is not checked, no insurance will be requested.

Block 7 – Complete **Block 7** with a precise description of the material or service desired. Include all specifications and requirements for the material or service as well as any references to previous correspondence or quotations. If specification drawings or other documents are incorporated as attachments, reference to the attachments must be made in this section. A continuation sheet is provided for this section of the order.

Block 8 – For radioactive material orders you **must** complete **Block 8** with the consignee's licensing authority information. In addition, for U.S. consignee's, a copy of the consignee's current license must be provided with the order. If the material or the consignee's facility are exempt from specific licensing, the enclosed *"Certification for Receipt of Radioactive Materials not Subject to Specific Licensing"* must be completed by the consignee and returned. Note that if the consignee is different from the buyer of the material, a document of confirmation of acceptance of the shipment is required from the consignee.

Block 9 – **Block 9** will be completed by the DOE or the DOE's facility contractor.

Block 10 – Complete and sign in **Block 10** as indicated. Orders not signed will be returned.

Notes:

All four (4) pages of the DOE order form, CA-10-90.Com Rev 3,must be returned. A facsimile return of the order to (865) 574-6986 is acceptable.

Web site: www.isotopes.gov

C:\Myfiles\WordDocs\InstructionsCA1090

DOE Form
CA-10-90.COM Rev 3
(07/01)

U.S. DEPARTMENT OF ENERGY

ISOTOPE AND TECHNICAL SERVICE ORDER FORM

This form is to be used by all persons (except foreign persons requiring source or special nuclear material) ordering source, special nuclear or by-product material, technical services, stable isotopes, cyclotron produced radioisotopes, or other related services from the U.S. Department of Energy (DOE) or DOE facility contractor.

1. To: ☐ U. S. Department of Energy OR ☐ DOE Facility Contractor

Name and Address:
Oak Ridge National Laboratory
Managed by UT-Battelle, LLC for the Department of Energy
P. O. Box 2008
Oak Ridge, TN 37831-6426

2. BUYERS ORDER NO.:

3. DATE:

4. SHIP TO

5. BILL TO:

6. VIA:

7. MATERIAL OR SERVICE

CATALOG ITEM NO. (if any)	SOURCE, SPECIAL NUCLEAR, BY-PRODUCT, OR CYCLOTRON PRODUCED RADIOISOTOPES: State isotope, chemical form, desired total activity, and desired specific activity. TECHNICAL SERVICE: State desired service and specification of final product. STABLE ISOTOPE: State isotope, chemical form, quantity, isotopic concentration, (specifying desired enrichments, minimum enrichments), and chemical purity (if applicable).	PURCHASE PRICE	RENTAL FEE
Shipping Schedule and Completion Date:	**Technical Service Charge (if applicable)**		
	Handling Charge (if applicable)		
	Total		

THIS ORDER CONSISTS OF FOUR PAGES AND IS SUBJECT TO THE TERMS AND CONDITIONS CONTAINED HEREIN. THE AUTHORIZED REPRESENTATIVE OF THE BUYER HAS READ, UNDERSTANDS, AND AGREES TO SAID TERMS AND CONDITIONS.

8. The Buyer certifies that the Buyer or the Buyer's representative is authorized to receive the above described source, special nuclear, by-product, or cyclotron produced material by: (*Check block and give license number and expiration date if applicable).*

a) ☐ **NRC or** ☐ _____ **License No.** _____ **which expires** _____, _____
Name of State — Month and Day — Year

b) ☐ **Exemption or General License provided by U.S. Nuclear Regulatory Commission (NRC) regulations.**

c) ☐ **Exemption or General License provided by** _____ **regulations.**
Name of State

9 Accepted for and agreed to by:

☐ **U. S. Department of Energy OR**

☐ **DOE Facility Contractor** _____

Printed Name _____

Signature _____

Title _____ **Date** _____

10. Authorized and agreed to by the Buyer:

Buyer _____

Signature _____

Printed Name _____

Title _____ **Date** _____

DOE Form
CA-10-90.COM Rev 3
(07/01)

U. S. DEPARTMENT OF ENERGY
ISOTOPE AND TECHNICAL SERVICE ORDER FORM

Continuation Sheet

CATALOG ITEM NO. (If any)	SOURCE, SPECIAL NUCLEAR, BY-PRODUCT, OR CYCLOTRON PRODUCED RADIOISOTOPES: State isotope, chemical form, desired total activity, and desired specific activity. TECHNICAL SERVICE: State desired service and specification of final product. STABLE ISOTOPE: State isotope, chemical form, quantity, isotopic concentration, (specifying desired enrichments, minimum enrichments), and chemical purity (if applicable).	PURCHASE PRICE	RENTAL FEE
	DELIVERY: Delivery is FCA Department of Energy facility from which the order is filled. Legal and equitable title and risk of loss or damage pass to the buyer when the material is delivered to the common carrier. Transportation and insurance charges are the responsibility of the buyer. ☐ Please check this box if insurance against loss or damage is desired during transport. If the box is not checked no insurance will be requested.		

Shipping Schedule and Completion Date:			
	Technical Service Charge (if applicable)		
	Handling Charge (if applicable)		
	Total		

ISOTOPE AND TECHNICAL SERVICES ORDER FORM
TERMS AND CONDITIONS

1. Definitions. "Buyer" means the person or entity placing this Order. "Government" means the United States of America. "Department" means the U.S. Department of Energy. "Contractors" means Department of Energy facilities' contractors and their employees who fill or participate in the filling of this Order, however, these Contractors are not agents of the Department. "DOE facility" means a laboratory, plant, or office operated by or on behalf of the Department.

2. Price of Material and Services. For material and services which are sold, the price or fee shall be fixed by the Department and in effect on the date of acceptance of this Order by the Department, said date shall be reflected in item 9 on page 1 of this Order.

For material which is leased, the Buyer understands and agrees that he/she/it must pay all charges, costs, and value of material losses as provided in the Agreement for Lease of Stable Isotope Material.

In the event of unusual circumstances which would cause the costs of materials or services to significantly exceed the purchase price of this Order, the Department shall not be obligated to continue or complete the Order by incurring costs in excess of this Order, and shall have the right to cancel this Order as specified in paragraph 13, unless the purchase price has been increased by written amendment to this Order.

3. Payment Terms and Interest. Payment shall be made within 30 days for domestic or 45 days for foreign orders from the date of the Department's or the Contractor's invoice, unless advance payment and/or a shorter period is specified in this Order.

All amounts payable under this Order (net of any applicable tax credit under the Internal Revenue Code, 26 U.S. C. 1481) shall bear simple interest from the date of delinquency until paid, unless paid within 30 days of becoming due. The date of delinquency is the date the Department or the Contractor mailed or hand-delivered the billing notice or invoice. The interest rate will be set at the same rate as the Treasury's Current Value of Funds Rate (prescribed and published by the Secretary of the Treasury in the Treasury Financial Manual Bulletin) for the period in which the debt became delinquent.

An administrative charge shall be imposed per delinquent invoice per 30-day period from the date of delinquency to cover the costs associated with collecting the debt, unless paid within 30 days of becoming due.

A penalty charge, accruing from the date of delinquency, shall be assessed at 6% per year on any portion of a debt that is outstanding for more than 90 days, including any interest and administrative costs.

Payments shall be applied first to accrued penalty charges, then to accrued administrative charges, then to accrued interest, and finally to the principal, pursuant to 4 CFR 102.13(f).

Interest, administrative charges, and penalty charges do not apply to a) other Federal agencies, b) other management and operating contractors of the Department, and c) State and local governments.

4. Government-owned Containers. When shipment of material pursuant to this Order requires the use of returnable government-owned containers, title to such containers shall remain in the Government. The Buyer shall keep the containers in good condition, will not use them for any materials other than the materials shipped therein, and will deliver them to a carrier designated by the Department for return to the point of shipment, transportation prepaid, within 30 days from the date of receipt by the Buyer of the shipment. The Buyer agrees to pay to the Department a demurrage charge on each returnable Government-owned container for the period of retention which is in excess of the said 30-day period.

5. Delivery/Risk of Loss of Material Sold.

a) Delivery shall be FCA the Department facility from which the Order is filled. The Department shall arrange for transporting the material from the Department facility. The Buyer shall pay all costs related to transporting the material. The Department shall put the material in the possession of the Buyer's carrier at the Department facility from which the Order is filled;

b) Legal and equitable title and risk of loss or damage shall pass to the Buyer when the material is delivered to the Buyer's carrier.

6. Delivery/Risk of Loss of Material Leased.

a) Delivery shall be FCA the Department facility from which the Order is filled. The Department shall arrange for transporting the material from the Department facility. The Buyer shall pay all costs related to transporting the material. The Department shall put the material in the possession of the Buyer's carrier at the Department facility from which the Order is filled;

b) Legal and equitable title shall remain in the Department, except that in the event the material is determined to be unacceptable for return to Department's inventory under the provisions of the Agreement for Lease of Stable Isotope, title to such material shall pass to the Buyer as of the date the Buyer is billed for the material by the Department;

c) Risk of loss or damage shall pass to the Buyer when the material is delivered to the Buyer's carrier;

d) Buyer shall return such material to the designated Department facility when required in Agreement for Lease of Isotope Material. Delivery shall be CIP the Department facility with freight prepaid by the Buyer and not charged to the Department. The Buyer shall arrange for transporting the materials utilizing a carrier designated by the Department. Risk of loss or damage shall pass to the Department upon acceptance by the Department of the material.

7. Labeling, Shipping and Receiving. Package labeling, shipping and receiving activities shall be performed in accordance with applicable Department, Department of Transportation, Department of Commerce, and Nuclear Regulatory Commission regulations.

8. Specifications. The Buyer shall promptly notify the Department in writing if any of the material does not conform to the specifications set forth in item 7 on page 1 of this Order. The responsibility and liability of the Government, the Department, and the Contractors upon verification of such non-conformances, shall be limited solely to making reasonable efforts to a) correct such non-conformances, b) replace with material which conforms to said specifications or c) make appropriate adjustments to the purchase price. The Department will reimburse the Buyer for reasonable costs of packaging and transportation incurred by the Buyer in returning to the Department any material which does not conform to such specifications.

9. No Warranty. All implied warranties are hereby disclaimed. Neither the Government, the Department, nor the contractors make any warranty, express or implied a) that material will be delivered or services performed at a specified time, b) that material accepted for technical or analytical services will not be destroyed, damaged, lost, or otherwise altered in physical or chemical properties in the process of performing the requested technical or analytical service, c) with respect to the accuracy, completeness or usefulness of any information furnished hereunder, d) that the use of any such information may not infringe privately owned rights, e) that the services, material, or information furnished hereunder will not result in injury or damage when used for any purpose or are safe for any purpose including the intended purpose, and f) that the services, material or information furnished hereunder will accomplish the intended results.

10. Liability. Neither the Government, the Department, nor the Contractors will be responsible for any injury to or death of persons or other living things, or damage to or destruction or loss of property, specifically including material supplied by the Buyer, or for any other loss, damage or injury of any kind whatsoever resulting from the performance of services or furnishing of material or information hereunder, by the Government, the Department, or the Contractors, to the extent such injury, death, damage, destruction, or loss is not caused by the negligence or willful misconduct of

costs of such storage. Unless this Order specifies that the material is to be returned to the Buyer, the Department may dispose of material supplied by the Buyer for technical or analytical services and the Buyer shall have no claim for the value or replacement of material disposed by the Department. The Buyer shall arrange for and bear all costs of transportation of material to and from (if applicable) the designated Department facility.

15. Severability. Should any provision of this Order be unlawful, void, or

the Government, the Department, or the Contractors.

11. Indemnification. To the extent permitted by state law, the Buyer agrees to indemnify and hold harmless the Government, the Department, and the Contractors from and against any and all liabilities, penalties, fines, forfeitures, claims, causes of action, and costs and expenses (including the costs of defense and/or settlement, including, but not limited to, attorney's fees), caused by, resulting from or arising out of, in whole or in part a) the breach of any term or provision of this Agreement, or negligent or willful act or omission, by Buyer, its employees, agents, officers, directors, or contractors, b) the failure of Buyer, its employees, agents, officers, directors, or contractors to fully comply with applicable statutory and regulatory requirements, c) performance by the Government, the Department, or the Contractors of acts, services, analyses, or tests, including furnishing material, required, specified, or directed by the Buyer to be performed or furnished under this Order to the extent the liability is not caused by the negligence or willful misconduct of the Government, the Department, or the Contractors.

12. Publication. The data produced under this Order will be provided to the Buyer who will be solely responsible for marking the data and removing the data from the facility by or before termination of this Order. The Department shall have the right to publish and use any data provided to or generated by the Department or the Contractors, and to permit others to do so unless such data is marked as "proprietary data" by the Buyer. The Department and the Government shall have unlimited rights in technical data (including proprietary data) which are not removed from the facility by or before termination of this Order. In addition, the Department and the Government shall have the unlimited right to perform similar or identical services for other buyers as long as the Buyer's proprietary data are not utilized. The Buyer agrees to deliver to the Department or the Contractors a non-proprietary description of the work to be performed under this Order.

13. Cancellation. The Department reserves the right to cancel this Order without further liability or cost a) in the event the license referenced to in item 8 on page 1 of this Order, which may be either the Buyer's or its authorized representative's license, is suspended, expired, canceled, or revoked, or does not authorize possession of the material, or b) when cancellation of this Order is determined to be necessary to the national defense, security, or environmental safety of the United States or due to lack of appropriated funds or facility capabilities or c) when the Buyer is delinquent on any payments due under this Order or any other Orders for isotopes or technical services related to isotopes from the Department.

The Buyer may cancel this order at any time by providing 180 day advance written notice to the Department. Buyer shall pay the Department, in addition to any costs owing under paragraph 3 above, any costs incurred by the Department in stopping the work and removing the Buyer's material as well as any other costs resulting from the cancellation.

14. Material Supplied by the Buyer. Material supplied by the Buyer may be held or stored by the Department in accordance with instructions of the Buyer, or in order to protect health, or to minimize other hazards to life or property. Buyer shall pay the Department all

for any reason unenforceable, that provision shall be severable and not affect the validity and enforceability of the remaining provisions of this Order.

16. Export Law Assurances. The Buyer agrees that it is responsible for and will comply with the United States export laws and the regulations thereunder relative to any export or re-export of material and/or information procured/obtained by the Buyer under this Order and any direct product thereof. The Buyer further agrees that neither such material and/or information nor any direct product thereof will be shipped, transferred or re-exported into any country prohibited by the United States export laws and the regulations thereunder or will be used for any purpose prohibited by such laws.

17. Facility Utilized. The Department, at its discretion, may fulfill its obligations under this Order through any of the DOE facilities.

18. Dispute Resolution. The parties agree to make good faith efforts to resolve any disputes using alternative means of dispute resolution. Substantive issues shall be determined in accordance with federal law. In the absence of federal law, substantive issues shall be determined in accordance with laws of the state of residence of the buyer at the time of the purchase. Should litigation be necessary all actions shall be brought in Federal District Court.

U.S. Department of Energy

Isotope Program

Contact Information

National Isotope Development Center (NIDC)

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U.S. Department of Energy

Isotope Program

Contact Information

Production Site Managers

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Brookhaven National Laboratory

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Idaho National Laboratory

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U.S. Department of Energy

Isotope Program

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Department of Energy Staff

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U.S. Department of Energy

Isotope Program

Enriched Stable Isotopes

Product Description

A large inventory of enriched stable isotopes is available and managed under an ISO-9001 quality program. Also, a wide variety of custom-order chemical and materials processing services are available from ORNL's Isotope Development Group. Inorganic compound synthesis is available to process inventory-form stable isotopes into the desired chemical forms to meet most customer needs. Metallurgical, ceramic, and high-vacuum processing methods are available to prepare enriched stable isotopes in a wide variety of chemical and physical forms. An indication of typical alternate chemical and physical forms available for each element is given on the individual enriched stable isotope catalog pages. The preparation of other alternate forms may also be investigated, upon request. A lease program for enriched stable isotopes is also available.

Current Capabilities Include

- Inorganic chemical conversions
- Arc melting and alloying
- Arc melting and drop casting
- Wire rolling
- Metal and ceramic powder consolidation
- Metal and ceramic hot-pressing
- High-vacuum evaporation to produce thin films and coatings
- Plasma sputtering to produce thin films and coatings
- Ion beam sputtering to produce thin films and coatings
- Crystal bar reduction processing
- Pyrochemical conversions
- Hot and cold rolling of metal foils
- Crucible melting and casting
- Wire swaging and drawing
- Vanadium-encapsulated neutron dosimeters

Contact Information

For Isotope Quotations/Orders:

National Isotope Development Center
Isotope Business Office
Phone: 865.574.6984
Fax: 865.574.6986
E-mail: contact@isotopes.gov

For Technical Information:

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Isotopes For Science, Industry, and Medicine
U.S. Department of Energy

A4787 Cert. ISO 9001:2008
UT-Battelle LLC

U.S. Department of Energy

Isotope Program

The Brookhaven Linac Isotope Producer (BLIP)

BLIP Description

Built in 1972. Uses high energy protons for radioisotope production by diverting excess beam of the 200 MeV proton Linac.

Proton Energies: Energies of 118, 140, 162, 184 or 202 MeV are diverted down a 30 m long beamline.

Target Channels: Six mechanically independent target channels are available. Most recently, target channels have been grouped into two boxes holding up to four targets each

Operating Cycles

Production of isotopes in the BLIP is dependent upon the operating cycle of the Linac. The schedule and duration of Linac operation is determined by the plans and funding of the nuclear physics experiments. The average BLIP intensity in this parasitic mode is about 20% less than full Linac output.

Radioisotopes

Beryllium-7*	Arsenic-73	Cadmium-109
Magnesium-28*	Strontium-82	Tin-117m*
Zinc-65	Yttrium-88	Yttrium-86
Copper-67	Technetium-95m*	Rubidium-83
Germanium-68	Technetium-96*	

*Production not scheduled

Currently in Development: Iron-52

Hot Cell and Processing Facilities

- Eight radiochemistry development labs
- Nine lead and steel hot cells
- Instrumentation lab for radionuclide assay by HpGe, gamma ray spectroscopy, NaI spectroscopy or liquid scintillation and elemental assay by ICP-OES, labeling determinations with HPLC

Contact Information

For Isotope Quotations/Orders:

National Isotope Development Center
Isotope Business Office
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Fax: 865.574.6986
E-mail: contact@isotopes.gov

For Technical Information:

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Director of Medical Isotope Research
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Isotopes For Science, Industry, and Medicine
U.S. Department of Energy

U.S. Department of Energy

Isotope Program

The ORNL High Flux Isotope Reactor (HFIR)

Reactor Description

Highest thermal flux and most versatile irradiation facilities in the world.
Thermal flux – up to 2.6 x 10^{15} neutrons/cm^2/sec at 85 MW. Operation since 1965.
Thermal/epithermal = 25–40/1.
22 day operating cycles – expected 6 cycles/year
Beryllium reflector replaced in 2002. Expected operation through 2030.

Irradiation Positions

Hydraulic Tube (HT) Facility
An HT facility with nine HT high-flux irradiation positions in high-flux core region permit insertion/removal of targets any time during reactor operation. Ideally suited for short-term irradiations, e.g., maximum 4.8 gm W-186/target loading possible.

High-Volume/High-Flux Large Target Positions
Core region also has unparalleled space for very large targets such as currently used for californium-252 production.

Peripheral Target Positions
Located on edge of flux trap. Permit thermal flux values of 1–1.7 x 10^{15} neutrons/cm^2/sec at 85 MW – 42 positions available for full-cycle irradiations. Accessible only during refueling and used for long-term and multi-cycle irradiations.

High-Volume Irradiation Positions also Available in Beryllium Reflector Region
RB units, CRAP holes, VXF positions, and so forth

Examples of Current Routinely Produced Radioisotopes
HT/core – Californium-252, Iron-55, Lutetium-177, Nickel-63, Selenium-75, Tungsten-188

Contact Information

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Isotope Program

LANL Isotope Production Facilities

Accelerator Description

The Isotope Production Facility (IPF) is a 100 MeV proton beam line spurred off of the Los Alamos Neutron Science Center (LANSCE) 800 MeV accelerator at Los Alamos National Laboratory. The target station has three irradiation positions. The facility was commissioned in 2004.

Currently IPF operates for ~3000 μA/h per year at a maximum current of 450 μA but is available to run in dedicated mode for additional operation hours. Current run cycle for LANSCE is from June to December. The capability is expected to be expanded in the next few years to maximize the current with which targets can be irradiated, and to allow for the irradiation of alpha-emitting targets.

Target sizes are nominally tens of grams.

Anticipated lifetime is 2024.

Irradiation Positions

High energy slot – 90–70 MeV. (p,xn) and (p,xnyp) reactions
Medium energy slot – 65–45 MeV (p,xn) and (p,αxn) reactions
Low energy slot – 30–0 MeV (p,xn) and (p,αxn) reactions

Cross Section Measurements

Facilities at the LANSCE accelerator also allow for the measurement of proton-induced cross sections at 800 MeV and 200 to 100 MeV using a proton beam with an ~100 nA current to optimize irradiation parameters and improve purity.

Hot Cell and Processing Facilities

The LANL hot cell facility at TA-48 contains <13 hot cells.

Examples of Current Routinely Produced Radioisotopes
Arsenic-73, Germanium-68, Strontium-82, Yttrium-88

Contact Information

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Isotope Program

Actinium-255 (10 d) and Actinium-225/Bismuth-213 (46 min) Generator

Production Method/Specific Activity – Routinely Available

Carrier-free actinium-225 obtained by chemical processing from decay of thorium-229 (from uranium-233). Specific activity = 5.80 x 10^4 Ci/g.

Produced to meet demand.

Parent of Bi-213.

Actinium-225 provided as radiochemical, either loaded on generator column, or provided as dry nitrate with generator components and instructions for loading.

Chemical Form

Actinium nitrate or actinium chloride solid, or actinium adsorbed on cation exchange resins (e.g., BioRad AG-50 or MP-50).

Chemical Purity

>99.9 %, with <0.1 µg/mCi for all detectable cations

Radionulidic Purity

^{225}Ac, >98 %; ^{225}Ra, <2 %; ^{224}Ra, <0.2 %; ^{229}Th, <1 x 10^{-3} %; all fissionable material, <5 x 10^{-3} %

Type A Shipment Levels

IATA limit = 6 TBq (~160 millicuries)

Contact Information

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Isotope Program

Arsenic-73

Production Method/Specific Activity – Routinely Available

Arsenic-73 is produced in the Los Alamos National Laboratory Isotope Production Facility via $^{nat}Ge(p,pxn)^{73}As$ reactions in the nominal energy range 90–70 MeV.

Properties

Half life/daughter	80.3 days to germanium-73
Major radiation	Gamma – 53.4 keV
Specific activity	>38 Ci/g (current batch) ~22,280 Ci/g (theoretical) >10 mCi/ml (concentration)
Radiopurity	>99.9% (exclusive of As-74)

Chemical Form

Arsenic (V) in 0.1M HCl

Type A Shipment Levels

IATA limit = 40 TBq (~1000 curies)

Contact Information

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Isotope Program

Cadmium-109

Production Method/Specific Activity – Occasionally Available

Cd-109 is produced at the Los Alamos National Laboratory Isotope Production Facility via $^{nat}In(p,X)^{109}Cd$ reactions in the nominal energy range 90–70 MeV. The current batch in inventory was processed in 2002 at the hot cell facility at Los Alamos National Laboratory.

Properties

Half life/daughter	462.6 days to silver-109
Major radiation	Gamma – 88 keV
Specific activity	>9 Ci/g (current batch) ~2,582 Ci/g (theoretical) >10 mCi/ml (concentration)
Radiopurity	>99.9% (exclusive of Cd-133m)

Chemical Form

Cadmium (II) in 0.1M HCl

Type A Shipment Levels

IATA limit = 2.0 TBq (~54 curies)

Contact Information

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Isotope Program

Californium-252

Product Description – Routinely Available

Produced in the Oak Ridge National Laboratory High Flux Isotope Reactor target positions. Multiple cycle irradiation: Thermal neutron flux = up to 2.6 x 10^{15} neutrons/cm^2/sec at 85 MW. Production method: Curium-244 oxide production targets undergo multiple neutron captures for the production of Cf-252 and other heavy element isotopes such as Bk-249, Es-253, and Fm-257.

Product form: High-specific-activity bulk Pd-Cf_2O_3 composite wire @ 500 µg Cf-252/inch or alternate forms.

Shipment Information

Bulk Cf-252 is encapsulated in stainless steel special form capsules. Quantities of up to 5 milligrams can be packaged in approved DOT Type A containers.

Contact Information

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Isotope Program

Germanium-68

Production Method/Specific Activity – Routinely Available

Germanium-68 is produced in the Los Alamos National Laboratory Isotope Production Facility and in the Brookhaven National Laboratory Brookhaven Linac Isotope Producer via $^{nat}Ga(p,xn)^{68}Ge$ reactions in the nominal energy range 30–10 MeV.

Properties

Half life/daughter	270.8 days to gallium-68
Major radiation	Positron – 511 keV
Specific activity	~6,638 Ci/g (theoretical) >10 mCi/ml (concentration)
Radiopurity	>99.9%

Chemical Form

Germanium (IV) in <1.0M HCl

Type A Shipment Levels

IATA Type A limits = 0.5 TBq (~14 curies)

Contact Information

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Isotope Program

Holmium-166m (1200 y)

Production Method

Holmium-166m obtained by neutron capture on Ho-165 target followed by chemical processing to remove impurities

Specific Activity

>1 mCi/g

Availability

MicroCi levels available throughout the year. Up to 5 milliCi can be made available by advance arrangements.

Chemical Form

Holmium nitrate or chloride in 0.1 M HNO_3 or 0.1 M HCl

Chemical Purity

>99.9 % (provided by the manufacturer of Ho-165 target)

Radionulidic Purity

^{166m}Ho, 99%; ^{160}Tb (72.3 d), 1%; ^{177m}Lu (160.1 d), ^{170}Tm (128.6 d), ^{152}Eu (13.3 y), ^{154}Eu (8.8 y), ^{141}Ce (32.5 d), ^{192}Ir (74 d), ^{60}Co (5.27 y), and ^{46}Sc (83.8 d), <0.1%

Type A Shipment Levels

IATA limit = 13.5 Ci

Contact Information

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Isotope Program

Lutetium-177

Production Method/Specific Activity – Available by Special Order

Produced in Oak Ridge National Laboratory High Flux Isotope Reactor Hydraulic Tube Facility (5–6 day irradiation: thermal neutron flux = up to 2.6 x 10^{15} neutrons/cm^2/sec at 85 MW).

High multi-curie levels of lutetium-177 can be provided as a radiochemical from the Lu-176(n,γ)Lu-177 reaction. Maximum specific activity = 50–80 curies/mg of Lu-176. Theoretical specific activity of Lu-177 is 109 curies/mg Lu

Lu-177m ($T_{1/2}$ = 160 days)/Lu-117 ratio at reactor push = ~ 7-8 x 10^{-5}.
cGMP program to provide a bulk pharmaceutical ingredient being considered depending on potential market size and interest.

Chemical Form

As chloride in 0.1M HCl solution crimp cap or screw cap glass V-vial

Type A Shipment Levels

IATA Limit = 0.7 TBq (~19 curies)

Contact Information

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Isotope Program

Nickel-63

Production Method/Specific Activity – Routinely Available

Nickel-63 produced in the ORNL High Flux Isotope Reactor central flux trap high-thermal-flux region (thermal neutron flux = up to 2.6 x 10^{15} neutrons/cm^2/sec at 85 MW) for up to 15 cycles.

Maximum nickel-63 specific activity = >10 curies/gm Ni by the Ni-62(n,γ) $\rightarrow$ Ni-63 route.

Chemical Form

Nickel chloride in HCl solution or as dry nickel chloride

Type A Shipment Levels

IATA limit = 30 TBq (~800 curies)

Contact Information

For Isotope Quotations/Orders:

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Isotope Program

Radium-223

Production Method

Ion exchange separation from actinium-227 nitrate

Specific Activity

Carrier-free Ra-223 in near equilibrium with its decay products

Availability

New! Routinely available during the calendar year or by special request through the National Isotope Development Center in amounts ranging from 18 MBq (0.5 mCi) to 6.47 GBq (175 mCi) per production campaign

Chemical Form

99.99% pure radium nitrate dry solid (soluble), near zero mass

Type A Shipment Levels

IATA limit = 0.007 TBq (189 mCi)

Contact Information

For Isotope Quotations/Orders:

National Isotope Development Center
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Isotope Program

Radium-226 (1600 y)

Production Method

Chemical processing of Ra needles

Specific Activity

Carrier-free (theoretical Sp. Act.: 0.989 mCi/mg)

Availability

Llimited quantities up to 20 mCi per batch available by special arrangements

Chemical Form

Radium nitrate

Chemical Purity

TBD

Radionulidic Purity

100% (recently was separated from Pb-210 daughters)

Type A Shipment Levels

IATA limit = 18 mCi

Contact Information

For Isotope Quotations/Orders:

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Isotope Program

Rhenium-186

Production Method/Specific Activity – Special Order

Produced in Oak Ridge National Laboratory High Flux Isotope Reactor Hydraulic Tube Facility (7-day irradiation: thermal neutron flux = up to 2.6 x 10^{15} neutrons/cm^2/sec at 85 MW).

Multi-curie batches of rhenium-186 provided as a radiochemical.

Maximum specific activity = up to15-17 curies/mg of Re-185 available by the Re-185(n,γ) Re-186 reaction.

Theoretical specific activity is about 188 curies/mg.

Chemical Form

As a sodium perrhenate in saline solution.

Type A Shipment Levels

IATA limit = 0.6 TBq (~16 curies)

Contact Information

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Isotope Program

Sodium-22

Production Method/Specific Activity – Occasionally Available

Sodium-22 is produced in the Los Alamos National Laboratory Isotope Production Facility via $^{27}Al(p,X)^{22}Na$ reactions in the nominal energy range 90–70 MeV. The material is produced on a limited basis, as it can take an entire year run cycle to produce curie quantities.

Properties

Half life/daughter	2.605 years to neon-22
Major radiation	Positron – 546 keV Gamma – 1,274.5 keV
Specific activity	>1,500 Ci/g (current batch) ~6,240 Ci/g (theoretical) >10 mCi/ml (concentration)
Radiopurity	>99.9%

Chemical Form

Sodium chloride in H_2O

Type A Shipment Levels

IATA Limit = 0.5 TBq (~13 curies)

Contact Information

For Isotope Quotations/Orders:

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Isotope Program

Strontium-82

Production Method/Specific Activity – Routinely Available - Provided as cGMP Non-Sterile Product (Pharmaceutical Ingredient)

Strontium-82 is produced in the Los Alamos National Laboratory Isotope Production Facility and in the Brookhaven National Laboratory Brookhaven Linac Isotope Producer via $^{nat}Rb(p,xn)^{82}Sr$ reactions in the nominal energy range 90–45 MeV.

Properties

Half life/daughter	25.55 days to rubidium-82
Major radiation	Positron – 511 keV
Specific activity	~62,300 Ci/g (theoretical) >10 mCi/ml (concentration)
Radiopurity	>99% (exclusive of Sr-85)

Chemical Form

Strontium chloride in 0.1–0.5M HCl

Type A Shipment Levels

IATA limit = 0.2 TBq (~5 curies)

Contact Information

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Isotope Program

Thorium-227

Production Method

Ion exchange separation from actinium-227 nitrate

Specific Activity

Carrier-free Th-227 in partial equilibrium with Ra-223 and decay products

Availability

New! Routinely available during the calendar year or by special request through the National Isotope Development Center in amounts ranging from 18 MBq (0.5 mCi) to 4.62 GBq (125 mCi) per production campaign

Chemical Form

99.99% pure thorium-227 nitrate dry solid (soluble), near zero mass

Type A Shipment Levels

IATA limit = 0.005 TBq (134 mCi)

Contact Information

For Isotope Quotations/Orders:

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Isotope Program

High-Purity Thorium-229 (7340 ± 160 y)

Production Method

Thorium-229 obtained by chemical processing of mass-separated uranium-233

Specific Activity

Two batches are available with the following specific activities:
Batch A: 0.16 µCi/µg of total Th
Batch B: 0.2129 µCi/µg of total Th (theoretical Sp. Act.: 0.2130 µCi/µg)

Availability

microCi levels available throughout the year

Chemical Form

Thorium nitrate, $Th(NO_3)_4$, xH_2O, solid (readily soluble in dilute inorganic acids)

Chemical Purity

>99.9% total thorium
Batch A: ^{229}Th (75.6 %), ^{230}Th (0.48 %), ^{232}Th (23.8 %)
Batch B: ^{229}Th (99.97 %), ^{230}Th (8.71×10^{-3} %), ^{232}Th (3.13×10^{-2} %)

Radionulidic Purity

Batch A: ^{229}Th (99.3 %), ^{228}Th (0.7 %)
Batch B: ^{229}Th (98.36 %), ^{228}Th (1.64 %)

Type A Shipment Levels

IATA limit = 13.5 mCi

Contact Information

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Isotope Program

Tungsten-188/Rhenium-188 Generator

Production Method/Specific Activity – Routinely Available - Provided as cGMP Non-Sterile Product (Pharmaceutical Ingredient)

Tungsten-188 produced in the Oak Ridge National Laboratory High Flux Isotope Reactor central flux trap high-thermal-flux region (thermal neutron flux = up to 2.6 x 10^{15} neutrons/cm^2/sec at 85 MW).

Generator provided as a radiochemical and has an extended useful shelf-life.
Processed tungsten-188 can also be provided.
Availability of cGMP-produced products (as pharmaceutical ingredients) expected in 2008.

Maximum tungsten-188 specific activity = 3–4 curies/gm W (one cycle) by the W-186(n,γ)W-187(n,γ)W-188(β- →)Re-188 route.

Large inventory of enriched (> 95%) tungsten-186 available at ORNL. Tungsten-186 can also be recovered from used generators for recycling.

Generator provided as a non-sterile cGMP bulk pharmaceutical ingredient ready for elution of rhenium-188. Detailed guidelines for setup, quality control, and bolus concentration methodology can be provided.

Rhenium-188 obtained carrier-free by positive elution of generator with saline.

Very high rhenium-188 specific volume solutions are obtained by post-elution tandem ion exchange column concentration (total rhenium-188 volume = < 1 mL).

Chemical Form

Rhenium-188 obtained as sodium perrhenate in saline eluant solution

Type A Shipment Levels

IATA limit = 0.3 TBq (~8 curies); generators up to 3 curies available as Type A package.

Contact Information

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Isotope Program

Yttrium-88

Production Method/Specific Activity – Routinely Available

Zirconium-88 decays via electron capture to produce Y-88. Zirconium-88 is produced in the Los Alamos National Laboratory Isotope Production Facility via $^{93}Nb(p,x)^{88}Zr$ reactions in the nominal energy range
90–70 MeV.

Properties

Half life/daughter	106.6 days to strontium-88
Major radiation	Positron – 760 keV Gamma – 1,836 keV
Specific activity	Not measured, carrier-free (current batch) ~13,900 Ci/g (theoretical) >1 mCi/ml (concentration)
Radiopurity	>99%

Chemical Form

Yttrium (III) in 0.1M HCl

Type A Shipment Levels

IATA limit = 0.4 TBq (~10 curies)

Contact Information

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Isotope Program

Isotope Availability News

Isotope	Application
Al-26	By-product of Si-32 production; used for biological research
Bk-249	Produced 22 mg target that led to the discovery of element 117; produced 26 mg for further super-heavy element research
Cf-249	Provided for actinide borate research
Cf-252	Re-established production in FY 2009; new 6-year contract for FYs 2013–2018
Li-6	Performed chemical conversion to metal form to establish kilogram quantities for use in the neutron detection devices
Np-237	Established inventory for dispensing bulk quantities and capability to fabricate reactor dosimeters (flux monitors)
Ra-224/Pb-212	Cancer metastases treatment
Se-72/As-72	Developed production capability for Se-72 for use in a generator to provide the positron emitter As-72
Si-32	Produced in the 1990s for oceanographic and climate modeling research, inventory depleted, processing of targets nearing completion to make isotope available again
Th-227/Ra-223	Established Ac-227 cows for the provision of Th-227 and Ra-223 (alpha emitters for medical applications)
W-188	Cancer treatment
W-188/Re-188	Therapeutic radioisotope cancer treatment
Y-86	Established production capability of the positron emitter Y-86

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Isotope Program

Isotopes Under Development

Isotope	Status
Ac-225	Developing production capability to supplement current decay-product-based supply
At-211	Funding production development at institutions to establish nationwide availability
Am-241	Initiated process to supply in association with an industrial consortium
C-14	Investigating economic feasibility of reactor production
Cd-109	Working with industry to assess product specific activity
Cm-243	Acquired curium with a high Cm-243 content for research applications
Co-57	Evaluating production of Co-57 for commercial source fabricators
Cu-64	Funding production development at multiple institutions
Gd-153	Pursuing feasibility of reactor production
Ho-166m	Investigating reactor production capability
I-124	Funding production development at one institution
K-40	Evaluating possibility of reactor production rather than electromagnetic enrichment
Li-7	Working to establish reserve for nuclear power industry to mitigate potential shortage
Pa-231	Purifying 100 mg for applications such as fuel cycle research
Sr-89	Investigating economic feasibility of reactor production
U-233	Evaluating acquisition for research applications
U-234	Investigating alternatives for reactor power monitors application
Zn-62/Cu-62	Funding production development for Zn-62 for use in a generator to provide the positron emitter Cu-62
Zr-89	Funding production development at multiple institutions

Display

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Isotope Program

Reactor-Produced Radioisotopes

DOE Operates Two High Flux Reactors

High Flux Isotope Reactor (HFIR) - ORNL

- Maximum production thermal neutron flux of ~2.6 x 10^{15} neutrons/cm^2/sec
- Hydraulic Tube Facility allows irradiation for short time periods to a full 22 day cycle
- High sample volume positions available
- Thermal/Epithermal ratios of 25 → 40

Advanced Test Reactor (ATR) - INL

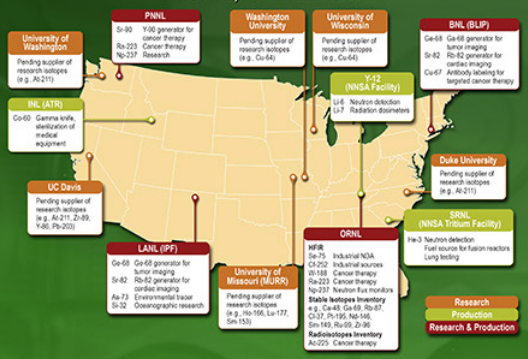
- Hydraulic Tube Shuttle System now available
- Maximum production thermal neutron flux of 2.5 x 10^{14} neutrons/cm^2/sec
- Cobalt-60 is currently produced

Routinely Produced Radioisotopes		
Cf-252	Bk-249	Co-60
Ni-63	Ac-255	Se-75

Special Order or Under Development	
Cd-109	Fe-55
Gd-153	Ho-166m
Lu-177 (HSA)	W-188

Isotope Development and Production for Research and Application Program

Research/Production Sites



Accelerator Produced Radioisotopes

Production and Processing Facilities Available at BNL and LANL

Isotope Production Facility (IPF) - LANL

- 100 MeV proton beam feed to IPF (up to 450 μA)

Brookhaven Linear Isotope Producer (BLIP) - BNL

- Proton beam tunable to 66, 93, 118, 139, 160, 181, 200 MeV (up to 115 μA)

Both IPF and BLIP have multiple target positions available with simultaneous irradiation in low, medium and high energy slots

Routinely Produced Radioisotopes			
Al-26	As-73	Cd-109	Cu-67
Ge-68	Na-22	Rb-83	Si-32
Sr-82	Zn-65		

Special Order or Under Development			
Ac-225	Be-7	Fe-52	Mg-28
Se-72	Tc-95m	Y-86	Y-88

Research and Development

- Therapeutic alpha emitters (At-211, U-233/Th-229/Ac-225/Bi-213, Th-228/Ra-224/Pb-212/Bi-212, U-230/Th-226, Th-227/Ac-227/Ra-223, Ra-225)
- Other therapeutic/theranostic isotopes (Sc-47, Cu-67, Sb-119, Rh-105, Re-186, W-188/Re-188, Pt radioisotopes)
- Isotopes for positron emission tomography (Ti-44/Sc-44, Fe-52, Mn-52, Zn-62/Cu-62, Cu-64, As-76, Y-86, Nb-90)
- Heavy elements (Bk-249, Cm-248, Cf-251)
- New radioisotope/extraction/separations technologies
- Accelerator and reactor isotope production targetry
- Stable isotope enrichment
- Isotope harvesting at rare ion beam facility
- Training in isotope production science and technology

Isotopes Harvested from Long-Lived Stockpiles

In addition to extensive capabilities for the reactor and accelerator production of radioisotopes, a number of isotopes are also available from the decay of long-lived stock materials or as fission products resulting from the processing of nuclear materials including:

Routinely Available			
Ac-225	Am-243	Cm-244	Cm-248
He-3	Pu Isotopes	Ra-223	Th-227
Th-229	U Isotopes		

Available in the Future
Am-241

Recent Accomplishments

- HSA Co-60: Reinstated domestic production for use in medical and industrial applications
- Ra-224/Pb-212 generators: Established production of radium-224/lead-212 generators for medical research
- W-188: Established routine production of bulk solution and W-188/Re-188 generators for medical research
- Cf-249: Supplied for actinide chemistry research
- He-3: Distributed excess inventory through annual auctions for research, medicine, and industry
- Bk-249: Produced for nuclear physics research leading to the discovery of element 117
- Si-32: Produced for environmental researchers investigating climate change
- Np-237: Enabled access to legacy inventory for use in nuclear science research
- Ac-225: Established a tri-lab research collaboration to investigate accelerator production

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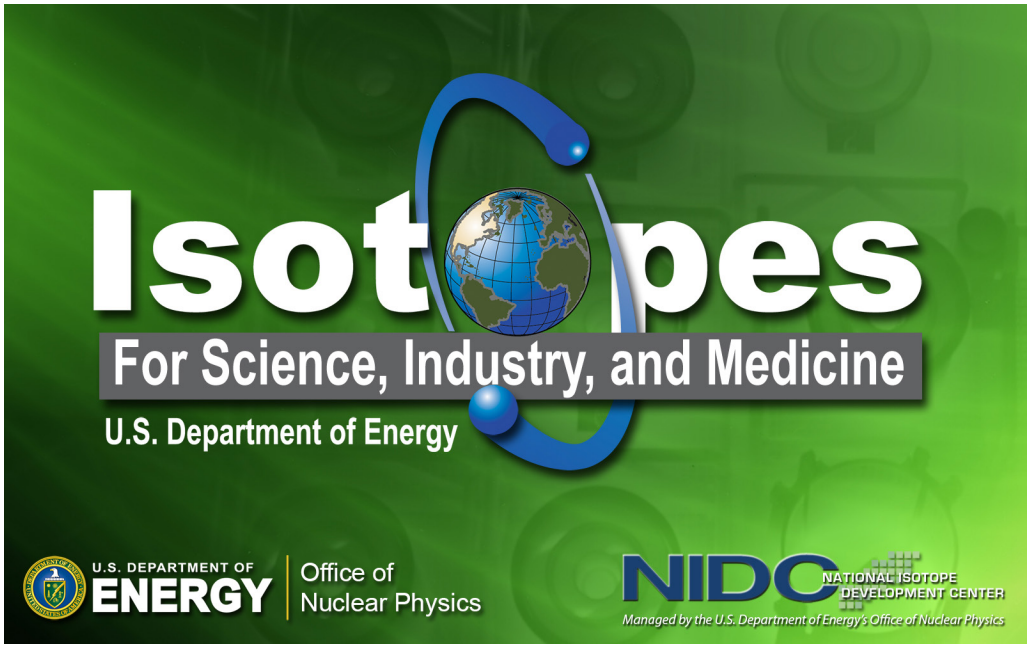
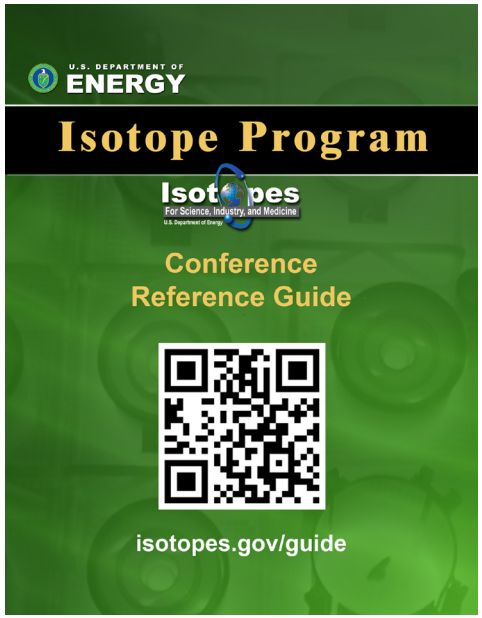
Isotopes For Science, Industry, and Medicine
U.S. Department of Energy

Podium and Table Signs





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Isotope Program

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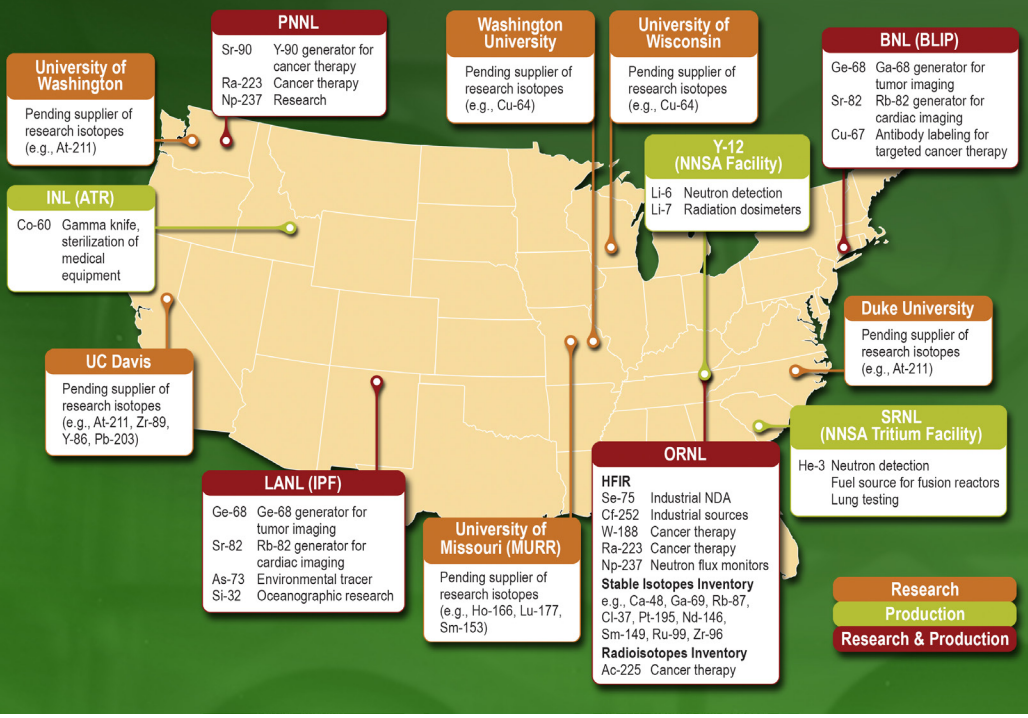

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U.S. Department of Energy

ORNL 2015-G01195/ch

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The National Isotope Development Center (NIDC) is managed by the U.S. Department of Energy's (DOE) Office of Nuclear Physics. The NIDC is a virtual service organization which interfaces with the user community and manages the coordination of isotope production across facilities. The NIDC's Isotope Business Office (IBO) manages the business operations involved in the production, sale, and distribution of isotopes.

Information and quotations for products and services can be obtained by contacting:
Isotope Business Office • Oak Ridge National Laboratory • Oak Ridge, TN 37831-6158
Phone: (865) 574-6984 • Fax: (865) 574-6986 • Email: contact@isotopes.gov

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